REPORT ON NUTRIENT OPTIMIZATION AT MONTANA MUNICIPAL WASTEWATER TREATMENT FACILITIES

October 2014

OVERVIEW

During the summer of 2014, The Water Planet Company supported the Montana Department of Environmental Quality (DEQ) effort to optimize nitrogen and phosphorus removal at the state's publicly-owned treatment works by providing two days of classroom training and making fifteen site visits to municipally-owned mechanical wastewater treatment facilities.

TRAINING

A two day classroom training session was held by Grant Weaver of The Water Planet Company in Helena on June 17 & 18, 2014. Attendees included municipal wastewater treatment plant operators from Big Sky, Boulder, Bozeman, Conrad, Dillon, East Helena, Helena, Kalispell, Polson, Whitefish, and a private contract operations company; Montana DEQ staff; a Midwest Assistance Program technician, and engineers from several design firms. A complete listing of attendees is provided at the end of this report.

The first day of classroom training was a discussion of nutrient removal fundamentals with a focus on understanding, developing, monitoring, and adjusting conditions to provide optimal habitats for nitrogen and phosphorus removal. Information on the use of ORP (oxidation reduction potential) as a process control strategy was shared. Case studies were presented; examples of municipal wastewater treatment plants that – without facility upgrades – realized nitrogen and/or phosphorus removal by operating existing equipment differently. And the environmental relevance of nutrient removal and Montana's implementation strategy were discussed.

For the majority of the second day of classroom training participants discussed their individual treatment facilities. Those not presenting interacted with the presenters – asking questions and making suggestions. Grant Weaver moderated the discussions and provided a brief review of each plant's situation, focusing on opportunities for improved nutrient removal.

PLANT VISITS

Eleven different municipal wastewater treatment plants were visited by The Water Planet Company's Grant Weaver. Four facilities were visited twice: Billings, East Helena, Helena, and Lolo. Montana DEQ and EPA Region 8 personnel were also on-site to provide technical support. The participants varied from facility to facility but included the following: Bill Bahr, Dave Frickey, Paul LaVigne, Jon Kenning, and John Arrigo (Montana DEQ) and Sadie Hoskie, Bert Garcia, Colleen Rathbone, and Tina Laidlaw (US Environmental Protection Agency).

A summary of the observations and recommendations for each treatment plant follows.

Big Sky

The Big Sky wastewater treatment facility serves the Big Sky ski resort and neighboring

residential communities. The aeration equipment at the Big Sky treatment plant is four to five times bigger than that of other similarly sized treatment facilities. On the day of the visit by DEQ's Bill Bahr and The Water Planet Company's Grant Weaver (August 21, 2014), the aeration diffusers were found to be torn. Plant superintendent Grant Burroughs had already ordered replacement equipment and was committed to replacing the diffusers once they arrived on site.

To reduce over-aeration and thereby reduce the shearing of the bacterial floc and improve nitrate-nitrogen removal, two major process changes were made during the plant visit. One. Three of the four 100 HP blowers were manually shut down so that only one of the 100 HP blowers would operate at any one time. Two. The air on/ air off settings were changed to increase the air off time.

Prior to the site visit an ORP meter was purchased and plant staff was provided with the following guidance. For optimal ammonia-nitrogen removal, the ideal end of react ORP is +100 to +150 mV (ammonia removal is optimized when it is consistently below 0.5 mg/L). For optimal nitrate-nitrogen removal, the ideal end of mix fill ORP is -100 mV (nitrate removal is optimized when it is 4-6 mg/L, or lower; nitrite should always be less than 0.5 mg/L).

A copy of the log sheet developed for the East Helena plant's use in monitoring field data results was provided and for the long-term, it was suggested that plant staff consider the purchase and installation of additional in-line probes such as ORP and TSS (total suspended solids).

A return visit during 2015 to provide follow-up technical support is recommended.

Billings

Two site visits were made. During the first visit (July 8, 2014) plant superintendent Susan Stanley gave DEQ's Bill Bahr and Grant Weaver of The Water Planet Company a comprehensive tour of the facility. The Billings plant is the largest in the State of Montana. It is a conventional activated sludge facility with the mechanical aeration equipment replaced by blowers and fine bubble diffusers. Modifications were made to the aeration tanks approximately ten years ago to provide anaerobic, anoxic and aerobic zones; but they aren't functioning as designed.

During the first visit, three concepts were discussed: (a) using the primary clarifiers differently, (b) using the gravity thickener as a fermenter and (b) cycling aeration equipment on and off to create alternating aerobic and anoxic conditions in the aeration tanks.

Prior to the second visit (August 19, 2014) plant staff experimented with cycling the aeration equipment. Due to extenuating circumstances, the experiment lasted only two days but encouraging results were achieved: ammonia removal remained unchanged but approximately one-third more nitrates were removed.

Notwithstanding the opportunities for nitrogen removal without capital investment, there is little interest in optimization and Billings is proceeding with a $50 million facility upgrade.

Bozeman

Plant superintendent Herb Bartle provided DEQ's Bill Bahr and The Water Planet Company's Grant Weaver a tour of Bozeman's plant on July 7, 2014. The facility is operating well and plant staff is satisfied with current operating procedures.

Columbia Falls

Technical support was provided in 2013, but in response to a complete turnover in supervisory personnel a site visit was made by The Water Planet Company's Grant Weaver on August 27, 2014. Plant supervisor Gene Woods not only actively participated, both of his employees engaged in the discussion.

The difference in reporting ortho-phosphate "as PO_4" and "as P" were explained. To simplify data review, a data recording form was provided. It was suggested that plant staff use their spectrophotometer to measure the orthophosphate concentration in the both the final effluent and the outlet end of the anoxic tank. And, to use test strips to measure the ammonia, nitrite and nitrate in the final effluent and the outlet end of the anoxic tank. And, to write down ORP readings from the inline meter located in the anoxic tank. And, use the information for process control as discussed below.

Equalization Basin

Because the phosphorus-rich sidestream flows go into the equalization basin, because the equalization basin flow is pumped into the bioreactor during periods of low flow (and therefore low BOD), because biological phosphorus removal requires a lot of BOD … It was suggested to push more of the influent flow through the equalization basin. And, to provide better mixing of the tank contents. And, use the equalization basin more or less as originally intended; as plant staff have been doing since the 2013 site visit.

RAS pumping

It was recommend that plant staff continue operating with as high of a return activated sludge (RAS) pump rate as the secondary clarifiers can take without adverse impact. And, to attempt to maintain a RAS pump rate that is approximately 100% of influent flow rate. Provided, that is, that the secondary clarifiers can accommodate the flow without adverse effect – and – further provided that DAF operations and sludge wasting are not adversely impacted.

Aeration Tank DO settings

The following recommended changes to the aeration tank dissolved oxygen settings were made … Zone 1: Increase the setting to 2.0 mg/L; in light of knowledge gained since last year's site visit, a higher upfront DO (dissolved oxygen) is better for biological phosphorus removal. Zone 2: Maintain the 1.5 mg/L DO setting, and increase it to 2.0 if necessary for ammonia removal. Zone 3: Maintain no aeration so as to minimize the amount of oxygen brought into the anoxic zone.

Phosphorus

Optimize biological P removal and minimize chemical P removal as follows.

Try to get as high as possible of a PO_4–P concentration in the anoxic tank sample; something over 20 mg/L. Accomplish this by (a) making the tank ORP low (approximately -200 to -250 mV) and (b) feeding approximately 200-250 mg/L BOD into the anaerobic zone. If the pre-anoxic tank ORP is low (-200 to -250 mV) but the phosphorus release is minimal, experiment with adding increasingly larger quantities of waste sludge back into the headworks.

And, making sure that there is lots of DO at the front end of the aeration tank; 2.0 being a good target. Review data daily and routinely discuss with staff – and – make adjustments.

Nitrogen

Maintain complete ammonia removal (effluent NH_4 less than 0.5 mg/L) by keeping a high mixed liquor and high ORP in the latter half of the aeration tank. "High" being +100 mV or more.

Optimize nitrate removal by (a) adjusting the internal recycle pump rate and (b) ensuring that there is 200-250 mg/L of BOD entering the anaerobic zone. It'll take some data gathering to figure out the optimal targets for the anoxic zone.

To find optimal conditions, correlate effluent Nitrate (NO_3) with anoxic tank ORP. It is likely that the lowest effluent NO_3 will occur when the anoxic tank ORP is somewhere in the range of -75 to -120 mV. When the optimal ORP range is found, adjust the internal recycle pump rates to provide an ORP reading that is +/- 40 mV of the optimal. When the ORP is too negative, increase the recycle pump rate. When the ORP is getting too close to zero, reduce the recycle pump rate.

A return visit during 2015 to provide follow-up technical support is recommended.

Conrad

DEQ's Dave Frickey and Grant Weaver of The Water Planet Company visited operator Keith Thaut at the facility on August 26, 2014. Following a two-day training class in 2012, Keith altered the plant's treatment process by cycling aeration equipment on and off. Doing so reduced effluent nitrogen by 82% from 26 mg/L to under 5 mg/L.

Turbidity data were not available, but a visual observation puts it extremely low, around 1 NTU. Conrad's is among the clearest effluents ever seen by the team.

The current mode of operation is as follows.

During the summer Conrad operates the aeration tank so that it receives air for 3 hours followed by 2 hours without any aeration. During the winter Conrad operates the aeration tank so that it receives air for 2 hours followed by 1½ hours without any aeration.

The sludge digester receives the same amount of aeration as the aeration tanks – plus, however long the two floating jet aerators are operated. To improve biological phosphorus removal it was suggested that the jet aerators operate only when sludge is wasted to the drying beds, if then.

Technical support on using the plant's colorimeter to perform ortho-phosphate testing (without the need for the digestion required for total-P testing) was provided. The Hach TNT vials can, for the most part, be used for either "reactive" or "total" phosphate. And, the following primer on understanding phosphorus test results was provided.

For purposes of wastewater treatment, there are two kinds of phosphorus: (1) the phosphorus that is dissolved in the water and (2) the phosphorus that is part of the MLSS (mixed liquor suspended solids) and therefore the effluent TSS. With the low effluent TSS produced at the Conrad facility (0-5 mg/L) the amount of phosphorus in the TSS is likely 0.05-0.25; the rest of the phosphorus being soluble phosphorus. Which therefore means that all but a very small amount of the effluent phosphorus (less than 0.25 mg/L) is ortho-phosphate, the "reactive" phosphate that the TNT test method provides without digestion.

Which means… Plants such as Conrad can use the TNT test to determine the reactive phosphate – provided they record the results as PO_4 - P, and not PO_4. Most spectrophotometers have three ways of reporting phosphate, generally with "PO_4" as the default. To get usable results it is important to toggle through the options and change the reading from "PO_4" to "PO_4 - P."

To optimize phosphorus removal, it was suggested that Conrad continue to return sludge from their sludge digestion tank. It was recommended that instead of continuously aerating the sludge tank that it instead receive little to no aeration.

A substantial reduction in dewatered sludge production was experienced by Conrad during the summer of 2014. It was explained that this occurred because bacteria are breaking apart and being consumed in the two environments: aeration tank and digester. And, that much of the carbon is being broken down to carbon dioxide (CO_2) and released into the atmosphere instead of being removed as sludge.

Conrad was advised that as they experiment with the amount of sludge pumped from the digester back into the aeration tank, they will need to adjust the amount of sludge wasted. For example, as the amount of sludge pumped into the aeration tank is increased, it will be necessary to also increase the amount of sludge wasted back into the digester. And, visa-versa: as the amount of sludge pumped into the aeration tank is reduced it'll be necessary to reduce the amount of sludge wasting. The more sludge pumped back from the sludge digester, the more VFAs (volatile fatty acids) and bio-P bugs ("PAOs" – phosphate accumulating organisms) that are returned to the aeration tank, and the better the phosphorus removal. And, the less sludge that will have to be pumped onto the drying beds. However, the more sludge pumped into the aeration tank, the greater the loading on the clarifier(s). Caution was advised.

Dillon

On August 20, 2014 Dillon Water Supervisor Jason Johnson led the following on a tour of Dillon's newly constructed mechanical treatment plant: Jon Kenning, John Arrigo, Paul LaVigne and Bill Bahr of DEQ and Grant Weaver of The Water Planet Company. Given that the facility is so new and the plant staff unaccustomed to operating a mechanical treatment facility, the technical support team recommended that plant staff concentrate on maintaining ammonia removal during the winter of 2014/2015.

In order to maintain a target ammonia concentration of 0.5 mg/L or lower, the technical support team recommended that staff measure ammonia in-house three days a week, daily if at all possible. To simplify monitoring it was recommended that test strips be used.

As a process control tool for conventional treatment it was recommended that an inline TSS (total suspended solids) probe be installed alongside the existing DO (dissolved oxygen) probe. And, that staff attend training classes and utilize free online resources to learn more about mechanical wastewater treatment facilities.

A return visit during 2015 to provide technical support with nitrate-nitrogen removal and biological phosphorus removal is recommended.

East Helena

Two visits were made to the East Helena wastewater treatment facility. On July 16, 2014 East Helena's Steve Leitzke led DEQ's Bill Bahr and Dave Frickey on a tour of the treatment facility.

On August 25, 2014 four EPA Region 8 officials (Sadie Hoskie, Bert Garcia, Colleen Rathbone, and Tina Laidlaw), DEQ staff (Bill Bahr, Dave Frickey, and Paul LaVigne), and Grant Weaver of The Water Planet Company met with East Helena's Steve Leitzke. A significant amount of data was provided.

The treatment facility is effectively removing ammonia but a considerable amount of nitrate remains in the effluent. The team recommended cycling the aeration blower on and off in order to create anoxic conditions suited to nitrate removal. So that the staff could become comfortable with operating the aeration zone without continuous aeration, it was recommended that the aeration equipment be manually turned off for an hour per day for a period of a week. And, to then manually turn it off for two hours daily for a second week. After which, assuming no problems arise, to install a timer so that the blower can be programmed to automatically cycle on and off. During the first visit plant staff was receptive to the concept but perhaps due to the demands of dealing with recent personnel changes had not done any experimenting.

A return visit during 2015 to provide follow-up technical support is recommended.

Helena

Two visits were made: July 16, 2014 and August 25, 2014. DEQ's Bill Bahr and Dave Frickey attended along with Grant Weaver of The Water Planet Company. The same team made technical support visits in 2012 and 2013. Mark Fitzwater and the entire Helena staff is fully engaged in the optimization process, notwithstanding some setbacks during the winter of 2013/2014 when the system was operated with one-half of the on-line aeration of previous years.

Nitrogen removal was the focus of the prior years. During 2014, with both aeration tanks (bioreactors) back in service, staff is focusing on biological phosphorus removal. Options for scouring the contents of the one in-service primary clarifier were discussed during the initial site visit and implemented before the second. Over the interim, effluent phosphorus dropped in half while nitrogen removal remained quite good.

Based on these results, the following operating strategy was agreed upon.

Target MLSS concentration with two bio-reactors in service

During the summer maintain a mixed liquor suspended solids (MLSS) concentration of 3500 mg/L. During the winter increase the MLSS to 4000 mg/L and, if the plant responds to the increase well, perhaps higher.

Process Control

Maintain the Mixed Liquor Recycle (MLR) rate as-is. Maintain the RAS rate as-is, or as needed to optimize clarifier performance. Keep the aeration DO settings as-is: 3.0 mg/L in the first aeration zone, 2.0 mg/L in the second, and 1.0 mg/L in the third.

As long as odors and/or freezing aren't an issue, continue using plant water to flush solids (and solubilize BOD) in the primary clarifier. During the work day: Pump to waste for 2 minutes and turn the primary waste pumps off for 10 minutes. No flush water during the day. After hours: Run the flush water for 5 minutes per hour. No wasting after hours.

Maintenance

Increase the frequency of staff cleaning of the in-line DO probes to twice per month.

Near-term Projects

In the bio-reactors, see if there isn't a way to either raise the water elevation so scum flows over the top of the scum trough and into the secondary clarifiers - or - lower the water level so the float goes under the scum baffles and into the clarifiers. If not, seriously consider removing the scum troughs.

Future Projects

For improved bio-P removal, extend the MLR outlet 20-30 feet into the anoxic/anaerobic basin. In the headworks, install fine screen and remove one or more sections of primary scum baffle to minimize odors in the primary clarifier. Cover primary clarifier(s) for odor control.

Because the plant staff is so engaged and so responsive to technical support, a return visit during 2015 to provide follow-up technical support is recommended.

Kalispell

Plant superintendent Curt Konecky provided DEQ's Paul LaVigne and The Water Planet Company's Grant Weaver a tour of Kalispell's nationally regarded wastewater treatment facility on July 14, 2014. The facility operates extremely well.

Upon receipt of a protocol for determining whether additional retention time in anoxic conditions will improve nitrate removal was received by email, plant staff performed laboratory testing and found little opportunity.

The option of utilizing incorporating one additional treatment cell for anoxic treatment was recommended by the technical team. As of the writing of this report, results were not available.

Lewistown

The Lewistown wastewater treatment plant produces a high quality effluent notwithstanding frequent equipment breakdowns. On July 9, 2014 DEQ's Dave Frickey and Grant Weaver of The Water Planet Company visited the facility. Visits were also made in 2013. The visits are providing supervisor Holly Phelps and staff with motivation to improve odor control and be more attentive to plant operations and maintenance. For these reasons, a return visit during 2015 to provide follow-up technical support is recommended.

Lolo

Two visits were made. On July 15, 2014 DEQ's Bill Bahr and Dave Frickey along with Grant Weaver of The Water Planet Company visited with chief operator Jasen Neese and HDR Engineer, Sean Everett. A follow-up visit was made by Grant Weaver on August 28, 2014. Between visits, the amount of aeration in the first of three aeration tank cells was reduced to a minimum. Doing so reduced phosphorus by 1-2 mg/L from 4-5 mg/L to 3 mg/L; one sample was 0.25 mg/L!

Total-N was typically around 25-30 mg/L. The ammonia concentration was less than 0.5 mg/L, but the nitrate was 20-25 mg/L. Nitrate dropped to 17 mg/L, reducing the total-nitrogen by over 5 mg/L.

At the recommendation of the technical support team, an ORP probe was purchased. An initial set of readings provided encouraging information: -50 mV in the first cell, +130 in the second, and +220 in the third. The plant has very limited control (ball valves on a common aeration header), but the following ORP targets were discussed: below -100 mV in the first cell, +100 to +150 mV in the second and third cells.

For the long-term the technical team agreed with the plant operator's idea of turning the air off completely in the first aeration zone and mixing the contents with some kind of mixing device; something that the operator agreed to research.

To control bacterial foam in the first aeration cell, it was recommended that the operator spray daily with a hand-pump pesticide sprayer containing 1/3 store bleach and 2/3 water.

The team provided information on free resource materials including on-line documents and webinars.

A return visit during 2015 to provide follow-up technical support is recommended.

Advanced Wastewater Training with/ Grant Weaver
Helena, Montana
June 17&18, 2014

Name	***System***
Keith Thaut	City of Conrad
Grant Burroughs	Big Sky Water & Sewer District
Greg Acton	City of Whitefish
Jesse Benbrook	City of Whitefish
John Wilson	City of Whitefish
Scott Anderson	Eng for City of Whitefish
Adam _____	Eng for City of Whitefish
Curtis Konecky	City of Kalispell
Del Phipps	City of Kalispell
John McDunn	DEQ Eng
Brandon Packer	City of Polson
Earle Cole Davis	City of Polson
Rob Dumke	City of Dillon
Stanley A. Roder	City of Dillon
Fred Irby	City of Helena
Mark Fitzwater	City of Helena
Charles T. Patera	City of Helena
Jeff Brown	City of Helena
Mark DeWald	City of Bozeman
John Boie	City of East Helena
Dennis Wortman	City of Boulder
Alden Beard	Private Engineer
Michele Marsh	DEQ Eng
Patrick Johnson	DEQ Eng
Erinn Zindt	MAP
Pete Boettcher	DEQ WPB Env Spec
Tommy Griffeths	DEQ WPB Env Spec
Dan Emter	City of Livingston
Kate Miller	Private Engineer
Ed Janney	Private Engineer
Lee Wolfe	Contract Operator